

## **Development of an integrated on-demand observing system**

Seiichiro Kigawa<sup>1</sup>

*1 Japan Meteorological Agency (JMA), Tokyo, Japan*

### **Abstract**

Data from an enormous number of surface observations made via various networks by national meteorological services and other organizations are expected to be available in the future. Such information needs to be collected and used to enhance capacity for monitoring of localized characteristics of extreme events. In connection, observations made by national meteorological services should focus more on high-frequency, high-resolution and three-dimensional monitoring using advanced instruments such as phased-array radars and hyperspectral sounders to improve monitoring and prediction skill.

Against this background, one of the major challenges of the next 20 years will involve the formulation of operational infrastructure for the dissemination, processing and storage of masses of surface observation data and temporally/spatially dense three-dimensional observation results.

To address this challenge, the Japan Meteorological Agency (JMA) works to enhance radar and satellite observation with methods enabling the acquisition of detailed observation data with focus on specific regions prone to disaster conditions caused by phenomena such as heavy rainfall. The first fruit of this work is the HimawariRequest target observation service based on data from JMA's Himawari-8/9 satellites, which was started in early 2018. The integrative operation of such methods is expected to support a favorable balance between the introduction of high-resolution state-of-the-art observation instruments and the implementation of compact observation systems.

JMA plans to promote the transfer of this effective and efficient observation system technology in the Asia/Pacific region. In its role as a Regional Specialized Meteorological Centre (RSMC) for nowcasting, JMA also plans to provide nowcasting products based on data from observations in the region. The development of such products is expected to improve capacity for disaster risk reduction (DRR) on an international scale.

### **1. An era of big data**

The ease with which photographs can be taken and shared today is owed to developments in the field of information communication technology. Such advances

have also produced an unprecedented variety of meteorological observation tools.

Against such a background, data from extensive surface observations conducted by national meteorological services and other organizations using various networks are expected to be available at increasingly lower cost in the future. In this context, such data can be collected from devices including mobile phones, cars, drones, web cameras and terrestrial digital television receivers. Over 100 million mobile phones are currently in use in Japan, and urban environments nationwide are expected to host autonomous cars by 2040. The provision of meteorological information may become a necessity as an incentive to such data collection via networks. Although novel methodologies may be required for quality control of these data, the ability to collect such vast amounts of information offers great promise for future development.

## **2. Meteorological disasters in Japan**

The high frequency of torrential rain events in Japan gives rise to a need for focus on disaster prevention. In 2014, 77 people died as a result of localized heavy rain in Hiroshima. In Fukuoka, even a 2017 daytime heavy rain event on a weekday resulted in more than 40 fatalities and washed away numerous houses. In 2018, over 220 people died due to the extensive effects of heavy rain in western Japan. In this way, localized intensification of weather-related disasters has become prominent in the country.

Against this background, JMA works to support the monitoring of localized characteristics of extreme events and to improve the provision of related information. The installation of forefront observation equipment and the systemization of observation networks are progressing, as observed with the launches of the Himawari-8 and Himawari-9 geostationary meteorological satellites in 2014 and 2016, respectively. The provision of 15-hour precipitation forecasts followed the introduction of High-resolution Precipitation Nowcasts in 2014, Real-time Risk Maps in 2017 and a supercomputer system upgrade in 2018. These developments represent JMA's comprehensive approach to addressing intense localized weather disaster conditions in Japan.

## **3. Bi-decadal plans toward 2040**

Plans for achievements to be made by 2040 must include the capacity for more detailed collection of both air and land observation data. Key characteristics are seen in data relating to the life-cycle of cumulonimbus formations. As clouds develop, droplets form and fall as heavy rain. Observation of this process ideally requires extensive observation at various points in the sky, which is challenging. In reality, radar is used for land-based observation, while in-orbit meteorological satellites observe sky areas.

Future plans involve focus on high-frequency, high-resolution three-dimensional monitoring using advanced equipment such as phased-array radar and hyperspectral sounders for improved monitoring and prediction.

When surface or sky observations areas are expanded, thereby intensifying spatial density, a new challenge emerges. A hundred million mobile observatories providing temperature and air pressure values every minute will produce at least 4 TB of data a day. Accordingly, observation throughout Japan using phased array radars with updates every 30 seconds could produce at least 20 TB of streamed data a day, and the volume of data from hyperspectral sounder observation of Japan's territory every 30 minutes could exceed 4 TB a day. In total, 28 TB of data per day may be generated, adding at least one order of magnitude to the amount of observation data currently collected in JMA's surface, radar and satellite observations.

Costs associated with data transmission, processing and storage have decreased significantly in the last 20 years, and demand for ongoing technological innovation and development remains high. Meanwhile, the body of meteorological big data produced by surface and remote-sensing observation continues to grow apace, and the development of a cost-effective system to accommodate the resulting high volume of information is a current challenge. Against this background, a major goal for the next 20 years involves the formulation of operational infrastructure for the dissemination, processing and storage of masses of surface observation data and temporally/spatially dense three-dimensional observation results.

#### **4. On-demand observing systems**

To address the challenges outlined above, JMA works to enhance radar and satellite observation via methods enabling the acquisition of detailed observation data with focus on specific regions prone to disaster conditions caused by phenomena such as heavy rain.

The first such initiative is the HimawariRequest service introduced in early 2018. Under this initiative, Himawari-8/9 is the world's first geostationary meteorological satellite to provide high-resolution full-disk images and rapidly updated regional images simultaneously based on requests from users in Asia/Pacific regions. Requesting parties are provided with real-time satellite images taken every 2.5 minutes over a 1,000 x 1,000 km area as shown in Figure 1.

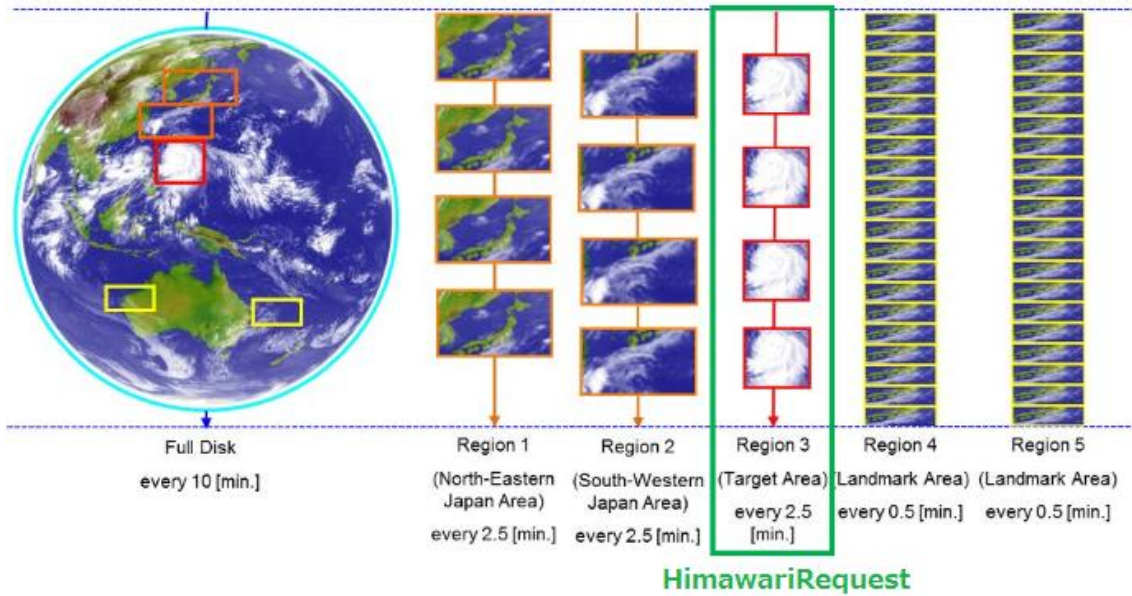


Figure 1 HimawariRequest target area

JMA is also in the process of upgrading its operational radars to enable high-resolution observation of certain regions and provide analysis data with a spatial resolution of 50 m around the radar site. Once the upgrade is complete, synchronized radars in the relevant area will enable more flexible observation.

Technological development is also expected to support on-demand surface observation. In situations where mobile phones are used to provide observation data and receive weather information, for example, it may be possible to introduce a mechanism by which the frequency of observation varies depending on the information received.

Taking rain as an example to illustrate the effectiveness of these approaches, statistical analysis for the latest 30-year period shows an annual average of around 120 rainy days (i.e., those with precipitation of 1 mm or more) per station in Japan and 1 or 2 days with precipitation of 100 mm or more. Specifying regions at high risk of heavy rain and focusing on related observation with higher resolution and spatial frequency will help to minimize data volumes as an advantage of on-demand observation. For weather phenomena other than rain, a sufficient margin is required and standard routine observation needs to be maintained, but overall system resource utilization can be optimized via specific regional observation with higher resolution and spatial frequency.

Synergistic benefits are also anticipated from integrative operation of land-based instruments, radar and satellites. Such operation is expected to support a favorable balance between the introduction of high-resolution state-of-the-art observation

instruments and the implementation of compact observation systems.

## 5. Collaboration

JMA plans to promote the transfer of this effective and efficient observation system technology in the Asia/Pacific region in its role as a Regional Specialized Meteorological Centre (RSMC) for Nowcasting via the provision of nowcasting products based on regional observation data. In product development, JMA plans collaboration with national meteorological and hydrological services wishing to use these products, with incorporation of feedback from end-users and related consideration to create optimal products. The table below summarizes the development plan.

FY	2018	2019	2020	2021	2022	2023-2027	
	Phase I		Phase II			Phase III	
Provision of materials and training for users	<ul style="list-style-type: none"> <li>Draw up product specifications for Phases II and III</li> <li>Provide user manual</li> </ul>		<ul style="list-style-type: none"> <li>Standardize product specifications</li> <li>Provide training</li> </ul>			<ul style="list-style-type: none"> <li>Provide mobile training centers</li> </ul>	
Satellite	Identification of Rapidly Developing Cumulous Areas (RDCA)	<ul style="list-style-type: none"> <li>Conduct evaluation to determine detection uncertainty</li> <li>Improve detection accuracy</li> </ul>		<ul style="list-style-type: none"> <li>Develop regional lightning nowcasting in Asia</li> </ul>			<ul style="list-style-type: none"> <li>Develop severe storm alert content for Asia</li> </ul>
	Himawari products (HCAI & HRPA)	<ul style="list-style-type: none"> <li>Launch Phase I website in December 2018</li> </ul>		<ul style="list-style-type: none"> <li>Develop regional integrated QPE/QPF in Asia</li> </ul>			
	JAXA/GSMaP	<ul style="list-style-type: none"> <li>Conduct evaluation to determine uncertainty in rainfall analysis and prediction</li> </ul>					
Radar	<ul style="list-style-type: none"> <li>Improve quality checking techniques</li> <li>Expand and enhance international exchange of observation data</li> </ul>						
Surface	Tokyo Action Plan		<ul style="list-style-type: none"> <li>Devise and implement training on quality improvement</li> </ul>		<ul style="list-style-type: none"> <li>Improve quality management</li> </ul>		<ul style="list-style-type: none"> <li>Enhance observation networks</li> </ul>

Table 1 JMA's RSMC 10-year plan for nowcasting

The plan comprises three phases toward the development of a high-level nowcasting product created using data from land-based instruments, radar and satellites. JMA collaborates with Asian nations under the Tokyo Action Plan 2018 (TAP2018) regarding surface observation instruments, works with signatory nations to the Southeast Asian Radar Network regarding radar, and collaborates closely with the Japan Aerospace Exploration Agency (JAXA) on satellite-related matters. The Agency also works closely with Deutscher Wetterdienst (DWD; the European RSMC for nowcasting). Inter-regional collaboration is expected to help enhance worldwide activity in this area.

JMA is also scheduling regional WIGOS center pilot phase operation to commence in 2019. In consideration of regional WIGOS center work in the provision of technical training to other nations, JMA combines the development of RSMC nowcasting products with such training to provide expertise in integrative on-demand observing system usage. The development of such products is expected to improve capacity for disaster risk reduction (DRR) on an international scale. Collaborative consideration and development are essential characteristics of the integrated on-demand observing system.